## REMARKS

This Amendment is timely filed in response to the Office Action mailed on August 6, 2003. This Amendment is accompanied by a change of correspondence address.

Claims 1-13 were examined in the Office Action, while claims 14-23 were not examined pursuant to a restriction requirement. Applicants hereby affirm the selection of claim 1-13 drawn to a mixing device pursuant to a restriction requirement and have herein withdrawn claims 14-23 drawn to a method of mixing.

Claims 1-6 and 8-13 were rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Pat. No. 5,842,787 to Kopf-Sill et al. (Kopf-Sill). Claim 7 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Kopf-Sill in view of Anderson et al. (U.S. Pat. No. 5,922,591).

In this Amendment, claims 1, 4, 6, and 10 have been amended. Dependent claims 24-32 have been added. No new matter has been added.

Before reviewing the cited art, Applicants will first review the claimed invention, as now recited in amended claim 1. Amended claim 1 recites a microchannel mixing device for electrohydrodynamic mixing of fluids including a microscale mixing channel having an inlet for receiving at least one fluid, at least one supply channel fluidicly connected to the mixing channel inlet for transport of the fluid into the mixing channel inlet, and at least two electrodes which when biased impose an electric field in the mixing channel. The electrodes have different geometries, such as different surface areas or orientations. The differing electrode geometries provide a non-uniform electrical field. At least one of the electrodes is disposed in the mixing channel.

Applicants note that the formation of an efficient electrohydrodynamic microscale mixing

device according to the invention is a surprising result given the low Reynolds Number for such a microscale device. A high Reynolds number corresponds to a turbulent flow, while a low Reynolds number corresponds to a generally laminar flow. Previous electrohydrodynamic mixing devices have used large tubes to ensure highly turbulent flows to achieve favorable mixing dynamics. The small microchannels disclosed herein limit flow turbulence by tending to force a substantially laminar flow. Thus, the highly favorable mixing results obtained from the claimed mixing device shown in the examples (see FIGs. 5(a)-(c) and FIG. 6 and associated description) indeed demonstrate a surprising result.

One method for transporting and mixing fluid samples and reagents is electrokinetic transport, such as provided by the teachings and devices disclosed by the principal cited reference, Kopf-Sill. In contrast, Applicants invention relates to an electrohydrodynamic mixing device. Before reviewing Kopf-Sill, some background regarding distinctions between electrokinetic and electrohydrodynamic transport and mixing and related devices appear warranted.

Electrokinetic transport relies on electroosmosis for fluid pumping through microchannels and electrophoresis for the separation of the components of a liquid mixture. Electrokinetic devices utilize electrodes at terminal ends of the device and generally utilize electrical fields on the order of several volts/cm to several hundred volts/cm. Substantially uniform electrical fields are set up. Electrokinetic transport, however, has limitations dictated by the physical properties of the fluids. For instance, electrokinetic transport cannot be used efficiently for nonpolar solvents, such as most organic solvents. Also, fluid mixing is generally limited to miscible aqueous systems and in most cases, depends on relatively slow diffusion

mechanisms.

Electrohydrodynamics concerns fluid motion due to externally applied electric fields. When a liquid contacts a biased charging electrode, electrochemical charge exchange reactions occur so that a portion of the liquid becomes electrically charged by interaction of the liquid with the charging electrode. Charged particles created at the electrode are directed by an electric field that is set up by a potential difference that is applied between the charging electrode and a counter electrode. Because one electrode has an exposed area which is much smaller than the other electrode, such as a near point source (See electrode 105 in FIG. 1), the desired non-uniform electrical field in the mixing channel is set up. Although electrokinetic transport alone can be used to mix most ionic and strongly polar miscible aqueous liquids, electrokinetic transport cannot be used to effectively mix nonpolar liquids, such as most organic solvents and immiscible liquids. Furthermore, electrokinetic transport relies on diffusion for mixing, which is a very slow process. In contrast, electrohydrodynamic mixing provided by the claimed device can be effectively and actively used to mix polar and nonpolar fluids, such as organic solvents and immiscible liquids.

Kopf-Sill discloses a microscale electrokinetic material transport systems for moving and directing material through and among microscale channel networks incorporated in microfluidic devices. As defined therein, "electrokinetic material transport systems" are said to "include systems which transport and direct materials within an interconnected channel and/or chamber containing structure, through the application of electrical fields to the materials, thereby causing material movement through and among the channel and/or chambers, i.e., cations will move toward the negative electrode, while anions will move toward the positive electrode."

Electrodes are disposed on the terminal ends of electrokinetic devices, such as the Kopf-Sill electrokinetic devices. For example, see FIG. 3 where electrodes 304 and 306 are shown at terminal ends of the device. In addition, although specific electrode geometries are not disclosed by Kopf-Sill, they can be assumed to be nominally the same as no advantage for electrokinetic transport arises from requiring differing electrode geometries, only additional set up complexity.

In contrast to the electrokinetic devices disclosed by Kopf-Sill, Applicants' claimed electrohydrodynamic device includes electrodes which have different geometries. This produces a non-uniform electrical field which facilitates the desired charge injection. Moreover, at least one of Applicants' claimed electrodes is disposed in the mixing channel. As noted above, both of the electrodes in the electrokinetic device disclosed by Kopf-Sill are located at terminal ends of the device. In view of the differences noted between Applicants claimed elecrohydrodynamic mixing device and the electrokinetic mixing device disclosed by Kopf-Sill, Applicants submit that amended claim 1 and claims dependent thereon are patentable claims.

Several dependent claims recite separately patentable limitations. Amended claim 4 now recites structure for isolating one of said electrodes from the fluid. For example, cover plate 340 shown in FIG. 3 can be used for this purpose. Such an arrangement can advantageously reduce the power supply current for a given bias condition. Both of Kopf-Sill's electrodes must be in solution for electrokinetic transport to operate.

Claims 24, 25 and 26 recite a spacing distance between the electrodes to be less than 450 µm, 100 µm, and 25 µm, respectively. As noted in Applicants' specification (see page 13, line 18-19), short electrode spacing permits the generation of high electrical fields required to generate electrohydrodynamic mixing using modest supply voltages. For example, as noted on

page 13 line 15 to page 14 line 2, 20 kV/cm fields can be generated using a potential difference of 50 volts using a 25 μm electrode separation. The electrode separation distance of Kopf-Sill's terminally placed electrodes appear to be on the order of millimeters.

Claim 28 recites a structure to propel the fluid comprising a pressure source, the pressure source applying a pressure differential across the mixing channel. Claim 31 recites two electrodes disposed in the mixing channel. Claim 32 recites two independent voltage sources which provide opposite polarities. Kopf-Sill does not disclose or suggest any of these features.

Applicants have made every effort to present claims which distinguish over the prior art, and it is believed that all claims are in condition for allowance. However, Applicants invite the Examiner to call the undersigned if it is believed that a telephonic interview would expedite the prosecution of the application to an allowance.

Although no fee is believed to be due, the Commissioner is hereby authorized to charge any fees which may be required by submission of this paper or during the prosecution of this application, to Deposit Account No. 50-0951.

Respectfully submitted,
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